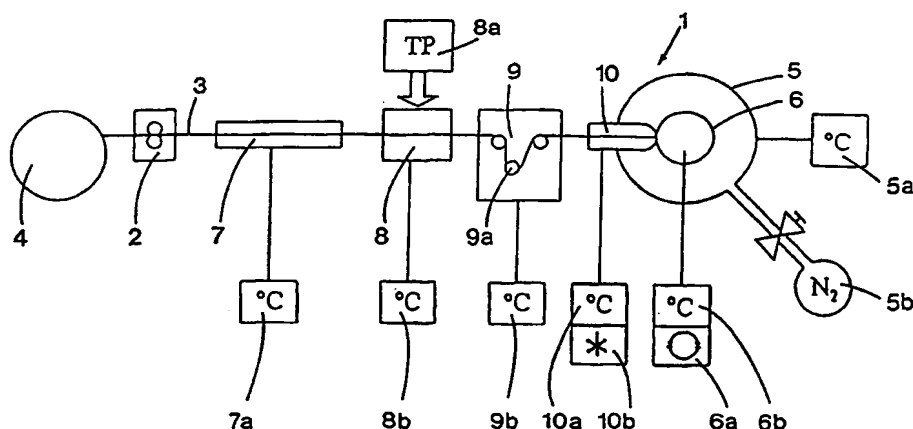




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(21) International Application Number: PCT/SE98/01581 (22) International Filing Date: 7 September 1998 (07.09.98) (30) Priority Data: 9703222-1 8 September 1997 (08.09.97) SE (71) Applicants (for all designated States except US): APPLIED COMPOSITES AKTIEBOLAG ACAB [SE/SE]; P.O. Box 13070, S-580 13 Linköping (SE). BOFORS AB [SE/SE]; S-691 80 Karlskoga (SE). (72) Inventors; and (75) Inventors/Applicants (for US only): VAARA, Jan [SE/SE]; Bygdgatan 357, S-583 31 Kinköping (SE). JOHANSSON, Nils, Göran [SE/SE]; Carl Hovbergsgatan 1C, S-633 53 Eskilstuna (SE). KROGAGER, Max [SE/SE]; Nya Tanneforsvägen 88, S-582 42 Linköping (SE). (74) Agents: WILLQUIST, Bo et al.; Willquist & Partners Patentbyrå AB, S:t Larsgatan 23, S-582 24 Linköping (SE).		(81) Designated States: NO, US, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE). Published <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i> <i>In English translation (filed in Swedish).</i>	

(54) Title: PROCESS FOR PRODUCING A HOLLOW BODY OF FIBRE-REINFORCED THERMOPLASTIC AND AN ARRANGEMENT FOR CARRYING OUT THE PROCESS



(57) Abstract

The present invention relates to a process for producing a hollow body of fibre-reinforced thermoplastic, and an arrangement for performing the process. In the process a continuous fibre bundle (3) is transported from means of transport (2). A section of the continuous fibre bundle (3) is heated up and the fibres in the section are impregnated with a thermoplastic. The impregnated fibre section is applied to a core-moulding tool (6), capable of controllable rotation about a shaft and located in an oven (5) with separate temperature control (5a). The angle or rotation of the core-moulding tool, together with the axial application position of the fibre section and the rate of feed of the fibre section are controlled in order to produce a hollow body with a pre-determined configuration on the core-moulding tool (6). The oven temperature is also controlled so that the thermoplastic on the core-moulding tool (6) is viscous during application. The tension in the fibre section is also controlled so that the fibres remain continuous and essentially extended whilst the process is being carried out. Application to the core-moulding tool (6) is terminated when the hollow body has taken on a pre-determined configuration, following which the rate of cooling of the hollow body is controlled by means of a separate temperature control for the oven (5a).

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Process for producing a hollow body of fibre-reinforced thermoplastic and an arrangement for carrying out the process

The present invention relates to a process for producing a hollow body of fibre-reinforced thermoplastic, as specified in the pre-characterising clause of claim 1.

5 The invention also relates to an arrangement for producing a hollow body of fibre-reinforced thermoplastic, as specified in the pre-characterising clause of claim 11.

10 Fibre winding is a well-known method for manufacturing composite products from fibre material such as carbon fibre, glass fibre etc. In the fibre winding process the fibre material is wound around a rotating core so that it forms a tube. The fibre material may be in the form of a bundle, which is formed from a number of continuous fibres. Before or after winding the fibre material is impregnated with a thermosetting plastic, which is allowed to cure when the winding is completed. In this way hollow bodies with a fibre angle of around 90° are produced, and with the aid of turntables also bodies with fibre angles down to 0°. The turntables are also necessary in order that the fibre bundles do not shift position in the thermosetting plastic, which before curing has a low viscosity.

15 In fibre winding according to the known art with thermosetting plastic impregnation, ovens are required for curing of the manufactured parts. When using pre-impregnated epoxy composite, cold storage rooms are also required for storing these. The chemical reactions associated with thermosetting plastics also involve environmental and health risks that must be counteracted by means of special ventilation installations and special routines.

20 It is therefore an object of the present invention to provide a process for producing a hollow body of fibre-reinforced thermoplastic, and an arrangement for producing a hollow body of fibre-reinforced thermoplastic, the process and the arrangement helping to eliminate or at any rate reduce the above-mentioned problems.

25 According to one embodiment of the present invention a process is provided for producing a hollow body of fibre-reinforced thermoplastic as specified by claim 1.

30 According to the present invention an arrangement is provided for producing a hollow body of fibre-reinforced thermoplastic as specified by claim 11.

Preferred embodiments of the process and the arrangement also have any or some of the characteristics specified by the respective subordinate claims.

The process and the arrangement according to the invention have several advantages.

5 By means of the process according to the invention, hollow composite bodies can be produced which withstand higher temperatures than composites with, for example, epoxy as matrix material, and which are lighter than the latter. The use of thermoplastics furthermore permits easier and faster manufacture than the use of thermosetting plastics, due to the fact that the curing process is eliminated. The products with thermoplastic
10 matrix material also have environmental advantages, since they are recyclable.

Products of composite material with thermoplastic matrix can moreover be reshaped after manufacture, which is not possible with products having thermosetting plastic as matrix material. Certain thermoplastics moreover exhibit greater impact strength than thermosetting plastics and also generally have better corrosion, flame and wear
15 resistance. Furthermore certain thermoplastics are geometrically and thermally stable, due to the fact that they have a low co-efficient of thermal expansion. Certain thermoplastics also have low moisture absorption and pronounced rigidity and damping characteristics. This means that thermoplastics can be tailor-made to suit different applications.

20 The use of thermoplastics permits winding with any fibre angles and geodetic winding, whilst non-geodetic winding also is possible, due to the capacity of the thermoplastic matrices to adhere to the underlying, which is not possible with the thermosetting plastics and means that fibre angles can be selected that are more suited to the strength
25 requirements demanded of the finished product. The capacity to adhere therefore also means that winding can be done without turntables if so desired.

The invention will be explained in more detail below with the aid of examples of
30 embodiments of the process and the arrangement and with reference to the drawing attached, which is a diagrammatic view of an arrangement according to the invention for carrying out the process according to the invention.

In the figure, 1 generally denotes an arrangement for producing a hollow body of fibre-reinforced thermoplastic. The arrangement comprises means 2 for continuously
35 transporting a continuous fibre bundle 3 from a fibre accumulation device 4, for example a bobbin or a spool. Examples of suitable fibres include glass, carbon or aramide fibres.

An oven 5 with separate temperature control 5a contains a core-moulding tool 6, capable of controllable rotation about a shaft, on which the hollow body will be formed.

The arrangement further comprises means 7, 8, 9 for continuously heating up and impregnating a transported section of the fibre bundle 3 with a molten thermoplastic.

5 The means of heating 7 are designed to heat up the section of the fibre bundle 3 to a temperature which is essentially equal to the melting temperature of the thermoplastic.

10 The means of impregnation 8, 9 comprise means 8 of producing a thermoplastic melt and means 8a of continuously feeding thermoplastic to the thermoplastic melt, for example in the form of an extruder. There are also means (not shown) of continuously passing the heated section of the fibre bundle 3 through the thermoplastic melt, so that thermoplastic is made to adhere to this section of the fibre bundle. The means of impregnation 8, 9 also comprise means 9 of continuously pressing the adhering molten thermoplastic into the fibre bundle 3 in the form of at least one heated breaking roller
15 9a, preferably a plurality, over which the fibre bundle 3 is designed to pass. The arrangement further comprises a means of heating (not shown), which is designed to heat up the press device 9 to a temperature essentially equal to the temperature of the thermoplastic melt.

20 The arrangement also has means 10 of continuously applying the heated and impregnated section of the fibre bundle 3 to the core-moulding tool in the form of an essentially toroidal winding nozzle 10, provided with at least one heating element (not shown) with separate temperature control 10a. Due to the design of the winding nozzle no separate compacting tool is required. The toroidal shape also means that the fibre
25 bundle 3 can be made to leave the winding nozzle 10 at any angle. The winding nozzle 10 can be heated up by the heating element so that the thermoplastic is prevented from solidifying in the nozzle and clogging the latter.

30 For applying the heated and impregnated section of the fibre bundle 3 to the core-moulding tool 6 there are means of continuously controlling the angle of rotation 6a and the application position 10b of the winding nozzle, together with means (not shown) of continuously controlling the rate of feed of the fibre bundle and the tension of the fibre section.

35 The arrangement comprises separate temperature control elements for controlling not only the oven temperature 5a and the winding nozzle temperature 10a, but also the temperature of the thermoplastic melt 8b and the means of heating 7 for the section of the fibre bundle and the means of heating the press device, so that suitable temperatures

can be obtained in the various parts of the arrangement, depending on what type of thermoplastic and what type of fibres are used and the geometry of the body being manufactured. The arrangement further comprises a separate temperature control element 6b for controlling the temperature of the core-moulding tool 6, so that it can be made, for example, to assume a temperature lower than the oven temperature.

The oven 5 also comprises means 5b for optionally feeding a protective gas, preferably, nitrogen, to the inside of the oven in order to prevent oxidation of the thermoplastic on the moulding tool.

In carrying out the process according to the invention for producing a hollow body of fibre-reinforced thermoplastic, a continuous fibre bundle 3, for example glass fibres, carbon fibres or aramide fibres, is transported from a fibre accumulation device 4. A section of the continuous fibre bundle 3 is heated up and the fibres in the section are impregnated with a thermoplastic. For impregnation, the heated section of the fibre bundle is led through a thermoplastic melt 8, to which additional thermoplastic is continuously fed. Molten thermoplastic is thereby made to adhere to this section of fibre. The fibre bundle has previously been heated to essentially the same temperature as the thermoplastic melt, in order to permit good adhesion of molten thermoplastic. The section of fibre is then made to pass through at least one heated press device 9 where it is made to run over at least one breaking roller 9a whilst the fibre tension is controlled so that the fibre bundle 3 spreads out on the roller 9a, the molten thermoplastic being pressed into the fibre bundle 3. The press device 9 is also heated to essentially the same temperature as the thermoplastic melt 8 so that the thermoplastic will have as low a viscosity as possible on impregnation and will therefore penetrate the fibre bundle 3 more easily.

The impregnated fibre section is applied to a controllable, rotatable core-moulding tool 6 located in a heated oven 5. The angle of rotation of the core-moulding tool together with the axial application position of the fibre section and the rate of feed of the fibre section are controlled in order to produce a hollow body with a pre-determined configuration. The oven temperature is controlled so that the thermoplastic on the core-moulding tool 6 is viscous during the application. The temperature of the core-moulding tool is controlled so that the thermoplastic on the core-moulding tool 6 begins to solidify closest thereto. The tension in the fibre section is controlled so that the fibres remain continuous and essentially extended whilst the process is being carried out.

When being applied to the core-moulding tool 6, the fibre bundle 3 is made to pass through an essentially toroidal winding nozzle 10, heated and with a separate temperature control 10a, and pressed against the core-moulding tool, by means of which the material applied to the core-moulding tool 6 is somewhat compacted.

5

Application to the core-moulding tool 6 is terminated when the hollow body has taken on a pre-determined configuration, following which the rate of cooling of the hollow body is controlled by means of a separate temperature control 5a for the oven. In order to protect the plastic against oxidation a protective gas, preferably nitrogen, is fed to the inside of the oven whilst the process is being carried out.

10

It will be obvious to a person skilled in the art that the invention is not confined to the embodiments described above, but rather lends itself to modifications within the framework of the idea of the invention defined in the following claims. For example, the arrangement according to the invention may be used in order to apply pre-impregnated fibres to the core-moulding tool in order to produce a body of fibre-reinforced thermoplastic.

15

Claims

1. Process for producing a hollow body of fibre-reinforced thermoplastic,
characterised in that it consists in: transporting of a continuous fibre bundle (3):
pre-treatment of a section of the continuous fibre bundle (3) so that this section has
an impregnation of molten thermoplastic; application of the impregnated fibre
section to a core-moulding tool (6), capable of controllable rotation about a shaft
and located in a heated oven (5); control of the angle of rotation of the core-
moulding tool together with the axial application position of the fibre section and
the rate of feed of the fibre section in order to produce a hollow body with a pre-
determined configuration; control of the oven temperature so that the thermoplastic
on the core-moulding tool (6) is viscous during the application; control of the
tension in the fibre section so that the fibres remain continuous and essentially
extended whilst the process is being carried out.
2. Process according to claim 1, **characterised in that** the pre-treatment consists in
heating up a section of the continuous fibre bundle (3) and impregnation of the
fibres in the section with a thermoplastic.
3. Process according to claim 2, **characterised in that** for impregnation the heated
section of the fibre bundle (3) is led through a thermoplastic melt (8), to which
additional thermoplastic (8a) is continuously fed, as a result of which molten
thermoplastic is made to adhere to the said section, following which it is made to
pass through at least one heated press device (9), as a result of which molten
thermoplastic is pressed into the fibre bundle.
4. Process according to claim 3, **characterised in that** the section of the fibre bundle
(3) with adhering thermoplastic is made in the press device (9) to run over at least
one breaking roller (9a) whilst the fibre tension is controlled so that the fibre
bundle (3) spreads out on the roller (9a), the plastic being pressed into the fibre
bundle (3).
5. Process according to either of claims 3 or 4, **characterised in that** the fibre bundle
(3) and the press device (9) are heated up to essentially the same temperature as the
thermoplastic melt (8).

- 5
6. Process according to claim 1, **characterised in that** the continuous fibre bundle (3) is pre-impregnated with thermoplastic and that the pre-treatment consists in heating a section of the continuous pre-impregnated fibre bundle (3) to a temperature essentially equal to the melting temperature of the thermoplastic.
- 10
7. Process according to any of the preceding claims, **characterised in that** in applying the fibre bundle (3) to the core-moulding tool (6) it is made to pass through an essentially toroidal winding nozzle (10), heated and with separate temperature control, pressed against the core-moulding tool.
- 15
8. Process according to any of the preceding claims, **characterised in that** the temperature of the core-moulding tool at the time of application is controlled by means of a separate temperature control (6b).
- 20
9. Process according to any of the preceding claims, **characterised in that** application to the core-moulding tool (6) is terminated when the hollow body has taken on a pre-determined configuration, following which the rate of cooling of the hollow body is controlled by means of a separate temperature control (5a) for the oven (5).
- 25
10. Process according to any of the preceding claims, **characterised in that** a protective gas, preferably nitrogen, is fed to the inside of the oven.
- 30
11. Arrangement for producing a hollow body of fibre-reinforced thermoplastic, **characterised in that** it comprises: means (2) for continuously transporting a continuous fibre bundle (3); an oven (5) with separate temperature control (5a); a core-moulding tool (6) capable of controllable rotation about a shaft; means of continuously pre-treating a transported section of the fibre bundle (3) so that this section has an impregnation of molten thermoplastic; means of continuously applying that section of the fibre bundle (3) impregnated with molten thermoplastic to the core-moulding tool (6); means of continuously controlling the angle of rotation of the core-moulding tool and the application position of the means of application, the rate of feed of the fibre bundle and the tension of the fibre section, and the oven temperature when applying the section of the fibre bundle impregnated with molten thermoplastic to the core-moulding tool (6).
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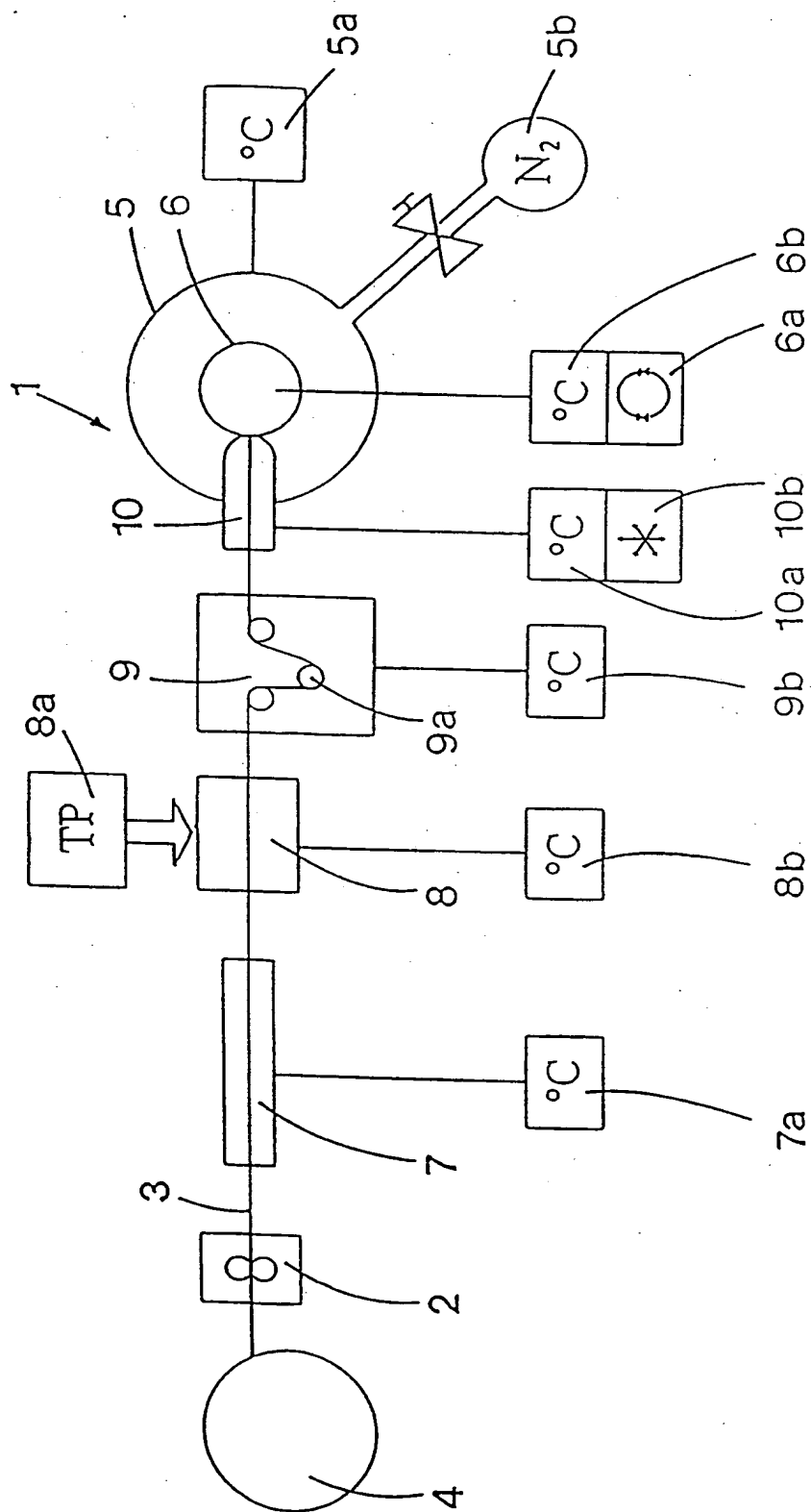
12. Arrangement according to claim 11, **characterised in that** the means of pre-treatment comprise means of heating up and impregnating a transported section of the fibre bundle with a molten thermoplastic.
- 5 13. Arrangement according to claim 12, **characterised in that** the means of impregnation comprise: means (8) of producing a thermoplastic melt; means (8a) of continuously feeding thermoplastic to the thermoplastic melt; means of continuously passing the heated section of the fibre bundle (3) through the thermoplastic melt so that thermoplastic is made to adhere to this section, and
10 means (9) of continuously pressing the adhering molten thermoplastic into the fibre bundle (3).
14. Arrangement according to claim 13, **characterised in that** the means (9) of pressing thermoplastic into the fibre bundle (3) comprise at least one heated
15 breaking roller (9a), over which the fibre bundle (3) is designed to pass.
15. Arrangement according to either of claims 13 or 14, **characterised in that** it comprises means of heating which are designed to heat up the section of the fibre bundle and the press device to a temperature essentially equal to the temperature of
20 the melting temperature of the thermoplastic.
16. Arrangement according to claim 11, **characterised in that** the means of pre-treatment comprise means (7) of heating up a section of a fibre bundle pre-impregnated with thermoplastic to a temperature essentially equal to the melting
25 temperature of the thermoplastic.
17. Arrangement according to any of claims 11 to 16, **characterised in that** an essentially toroidal winding nozzle (10), provided with at least one heating element with separate temperature control (10a), is arranged as means of
30 continuously applying the heated and impregnated section of the fibre bundle to the core-moulding tool.
18. Arrangement according to any of claims 11 to 17, **characterised in that** it comprises separate temperature control elements (5a, 10a, 8b, 7a, 9b) for
35 controlling both the oven and winding nozzle temperature and the temperature of the thermoplastic melt and the heated section of the fibre bundle and the press device.

19. Arrangement according to any of claims 11 to 18, **characterised in that** it comprises means of bringing the core-moulding tool (6) to a desired temperature together with a separate temperature control element (6b) for controlling the temperature of the core-moulding tool.

5

20. Arrangement according to any of claims 11 to 19, **characterised in that** the oven (5) comprises means (5b) of feeding a protective gas, preferably nitrogen, to the inside of the oven.

Fig 1



1
INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 98/01581

A. CLASSIFICATION OF SUBJECT MATTER				
IPC6: B29B 15/14, B29C 70/10, C08J 5/24 According to International Patent Classification (IPC) or to both national classification and IPC				
B. FIELDS SEARCHED				
Minimum documentation searched (classification system followed by classification symbols)				
IPC6: B29B, B29C, B32B, C08J				
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SE,DK,FI,NO classes as above				
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)				
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C. DOCUMENTS CONSIDERED TO BE RELEVANT				
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.		
A	Patent Abstracts of Japan, abstract of JP 20-48907 A ((KOUSEINOU JUSHI SHINSEIZOU GIJUTSU KENK), 19 February 1990 (19.02.90), abstract, & JP, A, 2048907 --	1-20		
A	Patent Abstracts of Japan, abstract of JP 90-66568 A ((FUJIKURA RUBBER LTD)), 11 March 1997 (11.03.97), abstract, & JP, A 9066568 --	1-20		
A	Patent Abstracts of Japan, abstract of JP 62-97590 A ((NITTO BOSEKI CO LTD)), 25 October 1994 (25.10.94), abstract, & JP, A 6297590 --	1-20		
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.				
<table style="width: 100%; border: none;"> <tr> <td style="width: 50%; vertical-align: top; border: none;"> * Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed </td> <td style="width: 50%; vertical-align: top; border: none;"> "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family </td> </tr> </table>			* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family
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21 January 1999		27 -01- 1999		
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 98/01581

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5225243 A (MARTIN BRÜCK), 6 July 1993 (06.07.93), abstract ---	1-20
A	US 5201979 A (TOMOHITO KOBA ET AL), 13 April 1993 (13.04.93), abstract -- -----	1-20

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/SE 98/01581

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5225243 A	06/07/93	CA 2037329 A	02/09/91
		DE 4006371 A	05/09/91
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